Atmospheric dispersion simulations: wind variability negligible or not?

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Abstract

Although (semi-)Gaussian models are frequently used to assess atmospheric pollutant dispersion, they are known to have a limited accuracy close to the source or in situations with complex air flow. In these situations, Computational Fluid Dynamics (CFD) could serve as an alternative. The aim of my PhD is therefore to evaluate the possibility of using CFD models to quantify the near-range dispersion of a radioactive pollutant as an alternative for the existing models.

Different CFD approaches can be followed to model atmospheric dispersion, particularly with respect to the turbulence. In any of these approaches however, it is important to incorporate effects of variable wind conditions, imposed by the atmosphere, to obtain good predictions of dispersion. When the Reynolds-Averaged Navier-Stokes (RANS) CFD approach is followed, as done during the first year of this project, a large disagreement between simulations and experimental data is usually observed manifesting itself as a large overestimation of the maximum concentration and a significant underestimation of the plume spread. This issue is sometimes addressed by weighing the steady-state RANS solution over the measured time distribution of the wind direction fluctuations. Unfortunately this results in an over estimate of the predicted plume spread.

We argue that this discrepancy is caused by the fact that fluctuations in wind directions observed in experiments are partially accounted for by the modelled turbulence in the simulations. The effective variability that should be imposed as a boundary condition to the simulation, therefore needs to be lower than the one measured experimentally. To this end, an approach is presented to estimate the level of wind-direction variability that has not been accounted for in the simulations.

The effectiveness of the approach is demonstrated by simulation of, and comparison to a selection of the well-known Project-Prairie-Grass experiments. The pollutant dispersion is modelled using a three-dimensional convection-diffusion problem in which the analytical profiles for velocity and eddy viscosity are prescribed, and in which the turbulent pollutant dispersion is modelled based on an eddy-diffusivity approach. It is shown that including the wind variability in the CFD simulations is essential to obtain more accurate results compared to a classical Gaussian model. In addition, accounting for the modelled variability further improves the accuracy in the tails of the concentration profiles.

As a next step in the project, the approach will be extended towards pollutant releases in the vicinity of buildings and vegetation.